MODIS SCIENCE DATA SUPPORT TEAM PRESENTATION

July 12, 1991

AGENDA

1. Action Items
2. MODIS Image Rectification Techniques
3. CASE Tool Recommendations
4. HDF Implementation for MAS
5. Network/Connectivity Discussion
6. Scenarios for MODIS Level-1 Processing

ACTION ITEMS:

05/03/91 [Lloyd Carpenter and Team]: Prepare a Level-1 processing assumptions, questions and issues list, to be distributed to the Science Team Members and the MCST for comment. (The list, the executive summary, information on the EOS Platform Ancillary Data, and a cover letter were delivered for signature and distribution.) STATUS: Open. Due date 06/07/91.

05/31/91 [Liam Gumley]: Establish a connection with the proper person at Ames Research Center for communication on MAS formats, an interface control document, agreements, etc. STATUS: Open. Due date 07/19/91

06/07/91 [Liam Gumley]: Speak to Alan Strahler, when he returns, regarding his MAS requirements. (Liam is on travel.) STATUS: Open. Due date 07/05/91

06/21/91 [Liam Gumley]: Obtain a copy of all available MAS Level-1B processing software and any existing documentation from the University of Wisconsin at Madison for porting to a system at GSFC. (Liam is now at Wisconsin for this purpose.) STATUS: Open. Due date 07/19/91

06/21/91 [Liam Gumley]: Generate a complete milestone schedule for conversion, installation and testing of all modules of the MAS Level-1B processing software at GSFC. Draw up an agreement between the SDST and Mike King of what will be done. STATUS: Open. Due date 07/19/91

05/31/91 [Al McKay and Phil Ardanuy]: Examine the effects of MODIS data product granule size on Level-1 processing, reprocessing, archival, distribution, etc. (Work is continuing.) STATUS: Open. Due Date 06/21/91

06/28/91 [Lloyd Carpenter and Tom Goff]: Prepare a detailed list of scheduler assumptions in relation to Level-1 MODIS processing scenarios. STATUS: Open. Due date 07/26/91.

06/28/91 [Lloyd Carpenter]: Prepare a letter to Bill Barnes inquiring as to whether or not the platform ancillary data will be included with the MODIS instrument data. (The letter was delivered for signature.) STATUS: Open. Due date 07/05/91.

06/28/91 [Tom Goff]: Prepare an estimate of the total cost of Cadre's Teamwork CASE tools and the Soft Bench umbrella product for the MODIS environment. (An interim report is included in the handout.) STATUS: Open. Due date 07/05/91.

12 July 91

SURVEY OF MODIS IMAGE RECTIFICATION TECHNIQUES

Knowledge requirements for EOS-A platform position and attitude are being reviewed within the EOS community and questions have arisen about the potential use of ground control points and image registration techniques to Earth-locate and align MODIS images. This document presents a plan for a quick-response survey of image rectification techniques to support the requirements review.

Background

For the EOS platform as a whole, a position-knowledge accuracy requirement of 50m (3 sigma, each axis) and an attitude-knowledge requirement of 108 arcseconds (3 sigma, each axis) is being considered[1]. Allowing for an additional 90 arcseconds of attitude uncertainty between the MODIS instrument base and the scan beam, the on-the-ground uncertainty in pixel location is 483m at nadir (3 sigma, each axis). Much larger uncertainties can occur off nadir. The question arises: Can ground control points and image registration techniques be used to reduce uncertainty below the present half kilometer for those products that require additional accuracy? A related question is: should the position and attitude requirements given above be altered to provide a more cost-effective system?

Since image location requirements are most stringent for MODIS-N over land (MODIS-N has two 250 m channels and five 500 m channels), answers may be sought for that domain. In a study of the effects of image misregistration[2], several of the MODIS land team members have specified a need for 0.2 pixel navigation accuracy (50m for the 250m bands) to obtain the desired 10% accuracy in some of their products.

Project Execution Plan

The proposed effort has been divided into four parts.

1. Survey of Methods to Achieve Automatic Image Rectification

The effort begins with a survey of methods to achieve automatic image rectification using previous knowledge of observed ground features. Techniques will be cataloged and the applicability and performance of these techniques in the MODIS environment will be estimated or evaluated.

Previous techniques used with Landsat and AVHRR will need to be adapted for MODIS needs. Attitude stability of the platform and the time stability of the MODIS instrument geometry must be investigated. Platform position knowledge may be important in resolving ambiguities when

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[1]Phone conversation with Dick Weber, MODIS-N Instrument Manager, July 9, 1991.

[2]Townshend, Justice, Gurney, and McManus, "The Impact of Misregistration on Change Detection", to be published.

a sufficient number of ground control points is not available and special studies reviewing the effect of the 50m position uncertainty on ground control activities are planned. Results of these studies will reflect on the number of ground control points needed and the maximum allowable separation between ground control points and study regions requiring precision registration (required nearness of GCPs to study regions).

At this point, copies of several relevant texts and journal articles have been obtained:

R. Bernstein, "Image Geometry and Rectification", Manual of Remote Sensing, R.N. Colwell, ed., Falls Church, VA: American Society of Photogrammetry. 1983, pp. 873-922.

A.P. Cracknell and K. Paithoonwattanakij, "Pixel and sub-pixel accuracy in Geometric correction of AVHRR Imagery," Int. J. of Remote Sensing, vol. 10(4,5), pp. 661-667, 1989

J.G. Moik, Digital Processing of Remotely Sensed Images., Washington, D.C.: NASA, 1980

A.K.I. Torlegard, "Some Photogrammetric Experiments with Digital Image Processing," Photogrammetric Record, vol. 12, pp.175-196, 1986

M.R.B. Forshaw, A. Haskell, P.F. Miller, D.J. Stanley, and J.R.G. Townshend, "Spatial Resolution of Remotely Sensed Imagery. A Review Paper.," Int. J. of Remote Sensing, vol. 4, pp. 497-520, 1983.

Interviews with key personnel are also planned. Dr. Ramapriyan has been contacted and an over-the-phone interview conducted. For the Landsat Thematic Mapper (TM), ground control points were primarily useful in resolving position (and not attitude) uncertainties. They used a very accurate look point model and the TM platform had a very accurate attitude measuring system. Consideration was given to such questions as how many control points are needed, what spatial distribution of control points is best, etc. The modeling was handled by GE. MODIS is very different from TM. From his TM experience, he expects that the 50m requirement of the land discipline team will be difficult to meet. The primary source of location errors for MODIS is attitude uncertainty, and it is a lot more difficult to correct for attitude errors (more ground control points are needed). A direct meeting with Rama has been tentatively scheduled for Wednesday of next week at 10:00 AM.

Dave Carnegie at the EROS Data Center has also been contacted. EDC has a lot of ground location experience gained from Landsat and AVHRR. However, some of those who were active in the earlier programs have since left employment at the center. He would like to arrange a meeting at EDC among those with potentially applicable experience to assess the present level of expertise. If an appropriate experience base presently exists, he would welcome a chance for a face-to-face meeting (either here or there) to discuss issues and techniques. Meetings with other AVHRR-experienced personnel are also anticipated.

2. Survey of Existing Databases for Ground Control Points

Existing databases of potential ground control points will be surveyed. Since MODIS ground location is particularly concerned with 250m channels that operate at 0.659 and 0.865 microns, all control points used in previous remote observation programs may not be applicable for MODIS processing. Potential seasonal effects on control point availability (e.g., clouds and snow) must also be evaluated.

3. Processing Impact of Image Rectification Techniques

The processing impact of promising techniques will be estimated or evaluated. Compute requirements often depend markedly on the accuracy with which the general location of a control point is known, i.e., searching a large area for a ground control point can require substantially increased resources. Differing techniques are applied for approximate (rough-in) and precise location, and if initial ground location is imprecisely known, successive application of increasingly accurate location techniques may be required to achieve satisfactory accuracy.

Experience with former projects may be particularly helpful in the estimation of impacts and resource requirements. The experience of Dr. Ramapriyan may be relevant. Dr. Yun-Chi Lu has been contacted, and although his experience is with semi-automated location for the PLDS, resource requirements may perhaps be projected from the location routines of the LAS. Others contacts will also be established to provide an additional basis for resource projections.

4. Alternative MODIS Image Rectification Using MISR

As an alternative to rectification done with MODIS-based ground control points, we will also consider the synergy between the MISR and MODIS-N instruments and the possibility that the stereo capability of MISR can be exploited to improve platform pointing knowledge. Note that MISR may have the capability to derive improved attitude knowledge at the MISR Payload Mounting Plate (PMP). This would be accomplished by using stereo views to build a Digital Elevation Model (DEM) [in cloud-free land areas only] that could be referenced against a global DEM. With position known, the unknown quantity would be the MISR line of sight, itself dependent on the platform's attitude.

We plan to discuss possibilities with the MISR team leader, Dr. Jan-Peter Muller, with EOS platform personnel (beginning perhaps with Ed Chang) and with GE Aerospace personnel. A key issue is the proper translation of the MISR PMP attitude to MODIS-N PMP attitude.

Since preliminary results of this study are wanted in the early September time frame, approximately six weeks are available for the first phase of the effort. We expect that this time is adequate to complete a survey of rectification techniques, to learn about the instrument and the platform, to talk with appropriate Goddard, EDC and AVHRR personnel, to survey potential sources of ground control points, to estimate the impact of image rectification activities, and explore the possible use of MISR to provide improved attitude information.

C.A.S.E. Recommendations

A complete Computer Aided Software Engineering (CASE) environment can be divided into several components. A front end design tool to perform diagraming, a back end tool to perform code generation and debugging, a configuration management (CM) tool to handle multiple access to the design elements, a publication package, a data dictionary depository to hold all the data required of the other tools in the CASE environment and a "glue" to get everything to talk together. Here are my recommendations for the CASE tools to be used in the near future for the MODIS project that will allow expansion as the project grows. They are listed in recommended purchasing order.

Graphical editors and data depository (Front End). This is the basic preliminary design tool for the front end design. Cadre's TeamWork is a full CASE implementation that can reside on multiple vendor UNIX platforms. Note that TeamWork was selected for the Space Station and we may be able to purchase through their contract.

TPE - core $8000 for one seat
SA,RT,SD editors - $1750 each per seat
C source builder - $1500
TOTALS - $14750
The above are subject to a 30-50% discount to be negotiated.
Support is not included.

Code Generation and Debugging (Back End). The best platform independent tool is Hewlett-Packard's SoftBench. It provides a "glue" for all the other tools that have been encapsulated as well as a code editor, assembler lister, debugger, etc. The product handles C and FORTRAN code on all platforms, with C++ and ADA on HP platforms (currently). This product is supported by HP on HP and SUN machines, with licenses for IBM and MIPS based (SGI) machines.

SoftBench - $2300 per seat
GSA discount not included.
Support is not included.

Configuration Management. CaseWare's AMPLIFY CONTROL graphical configuration management

(details forthcoming)

Publishing. Frame's FrameMaker (currently) or Interleaf Technical Publishing Software (future).

Reverse Engineering. These products input source code and create structured charts. Either Cadre's revC, or revF; or McCabe Test Tools.

These are being investigated for future use.

SCENARIOS FOR THE MODIS LEVEL-1A AND LEVEL-1B PROCESSING

27 June 1991

1. Normal Processing:

Normal MODIS Level-1A and -1B processing will be done as required input data elements are received and as the necessary EOSDIS compute resources become available for MODIS use. Instrument data packets and required ancillary data will be received and stored in the DADS until Level-1 processing begins. It is expected that the EOSDIS scheduler will monitor data availability at the DADS, match available data against a list of specific items that must be available before a process is initiated, and initiate processing as input data requirements are met and machine resources become available.

o Simplest Case.

In the simplest scenario, instrument engineering data contained in a processing granule will be sufficient to characterize instrument behavior (calibrate the instrument) during the time interval when the data granule was acquired, and processing of a data granule can begin when a complete set of instrument data packets for the granule has been received and required platform ancillary data for the granule is available.

o Multiple Granules Required.

If information from preceding or following granules is required to characterize instrument behavior for the contemporary granule, alternative procedures must be followed. One possible processing scheme would access conterminal granules in increasing time order and maintain a long-term running record of relevant engineering parameters from contemporary, preceding, and following granules as the granules are accessed and processed. Information in the calibration record would be updated as new granules are accessed and as data from old granules becomes irrelevant. This is basically a "sliding window" approach. In this case, the scheduler would have to ensure the availability of a continuous record of input data before processing is initiated and granule processing tasks would have to be initiated in time increasing order.

An alternative processing scheme would extract relevant instrument engineering parameters (perhaps generating a calibration support product) in an early pass through the data, store the information in a separate record, and access that record as required to complete processing in a subsequent pass through the data. By this scheme, processing granules would not necessarily have to be accessed in increasing time order.

o MODIS Instrument Data.

Standard (i.e. non-"quick-look") MODIS data received at the DADS has already been error corrected, if possible, has been error flagged, if correction is not possible, and has been bit order corrected (if time order reversal of received data is required). Earlier processing has also accounted for all received MODIS instrument packets, identified any missing items, and eliminated any duplicate data packets that may have been created during successive playbacks of the on-board tape recorders.

o Level-1A Processing.

The MODIS Level-1A product is primarily intended to provide a permanent record of MODIS instrument data; it can be reversed to recover Level-0 data, if required. The Level-1A product receives minimal processing. During Level-1A processing, spacecraft ancillary data will be appended (but not applied) to the instrument data to provide a single, integrated source of all the data required to complete Level-1 processing, successive instrument packets are concatenated to produce the Level-1A data granule, and metadata is generated to facilitate data storage and user retrieval of data. To preserve the integrity of the original data record, it is not currently planned to unpack (byte-align) the MODIS data during Level-1A processing.

o Level-1B Processing.

The primary functions performed during Level-1B processing include the Earth-location of MODIS pixels using platform ephemeris and attitude information (and possibly ground control points), the radiometric conversion of sensor outputs to obtain physical radiances at the sensor (sensor calibration), and data-handling and accounting functions required to control data flows. Level-1B processing will also include quality checks to assure proper MODIS instrument operation. Results of the Level-1B instrument checks will be routinely provided to the MCST and instrument controllers, if desired. The overall quality of the data product will be monitored in a separate data quality assessment step at the end of Level-1B processing.

2. Quick-Look Processing:

In most cases, the need for quick-look processing can be anticipated. For example, in planned field experiments, an early look at the MODIS data may be a key element in the decision making process directing the ground portion of the experiment. The investigators will coordinate their quick-look processing requirements with the MODIS Team Leader who will provide final approval and coordinate the effort with CDOS and other elements of the EOSDIS.

A MODIS quick-look processing request will be sent to the EOSDIS specifying which data are to be processed. The EOSDIS will adjust priorities and expedite the flow of the data through the CDOS. The SCA will initiate the MODIS Level-1A quick-look processing soon after the data are available.

Quick-look processing may require time-ordering, redundancy elimination, and quality control measures not normally required for standard MODIS processing. However, quick-look processing will be executed using the same version of software as normal processing, and the Level-1A software will be designed to perform these functions.

Platform ancillary data may not be available in time for quick-look processing. In this case an alternate source, such as a predicted ephemeris, will be specified and made available by the EOSDIS for the required platform position and attitude data.

The Level-1A process will notify the scheduler when quick-look processing is completed. The scheduler will then initiate the MODIS Level-1B quick-look processing, which will be executed using the same version of software as normal Level-1B processing.

3. Metadata Generation:

MODIS metadata consists of information describing the MODIS data which is obtained or derived from the data sets, and which provides an understanding of the content or utility of the data set. Metadata may be used to select and evaluate data for a particular scientific investigation.

Beginning at Level-0, each successive processing level will generate and append metadata as part of the data product. The metadata associated with the input product are updated to reflect further derived information. Previous metadata items are retained to allow backward tracking of information to the original source. This information can be used for debugging and quality assurance determination. For example, the CDOS Reed-Solomon error statistics can be maintained with the mapped Level-3 product as an indication of the quality of the original data that went into the product. Metadata derived in the beginning of the processing chain will provide information which is useful for the generation and assessment of products later in that chain.

Care must be taken in the interpretation of metadata in some cases. For example, error statistics for a granule of Level-1A data could be misleading when each Level-1A granule is subdivided into several granules at Level-1B. Some of the Level-1A statistical information may not be correct when applied to the subset of data which went into a particular Level-1B granule, etc. The reverse situation occurs, for example, when many Level-2 granules are used as input to a Level-3 process which generates an average value and a secular rate of change for some parameter. However, with a complete trail of metadata information, the user should be able to trace the heritage of his data and properly interpret his results.

4. Browse Data Generation:

Since the MODIS science team members have not indicated a requirement for Level-1A browse, no MODIS Level-1A browse products have been planned.

The MODIS Level-1B browse process will be designed for easy adaptation to future technology developments without affecting the standard Level-1B process. To this end, the MODIS Level-1B browse process will be separate from the normal Level-1B process. After each execution of the Level-1B process, the Level-1B browse process will be initiated to generate the standard Level-1B browse product.

Specifics of the Level-1B browse product will be defined by the MODIS science team. This product might include, for example, a time sequence of "scenes", each of which is generated by sub-sampling the pixels of a rectangular area on the earth's surface. For each pixel, the recorded signals would be included (at reduced resolution) for a specified subset of the available frequency bands. Users would "call up" these browse scenes at will.

If the EOSDIS supports an extended browse product, then users could, at any time, request that special Level-1B browse scenes be generated from archived Level-1B data. In this mode, for example, the user would specify times, earth locations, and frequency bands to be included in the browse scene. The success of this extended browse capability could reduce the need for archiving standard Level-1B browse products.

5. Processing Previously Missing Data:

In normal operations, processing of a MODIS Level-1A or -1B data granule includes all of the data which should be in the granule. However, there will be occasions when some of the data are missing at the time of normal processing. In fact, this will happen frequently when the time boundaries of blocks of Level-0 data scheduled for Level-1A processing do not correspond to Level-1A granule boundaries.

If the previously missing data correspond to one or more complete granules, they will be processed in the normal mode. Otherwise, special handling will be required.

One possible scenario for processing previously missing data would be to have all of the data processed to Level-1A as it is scheduled, and then have the incomplete granules combined by a utility process. A shortcoming of this scenario is that, in some cases, not all of the data in a granule would have been processed at the same time. In fact, data within a granule could have been processed using different versions of the software.

Another possible scenario would be to reprocess all of the data within a granule whenever previously missing data is received. If this causes excessive inefficiency, the reprocessing could be done for only those cases where different versions of the software or the ancillary data are involved.

6. Reprocessing:

A. New Version of Software:

It is unlikely that the original, at-launch, version of the software will be used throughout the mission without revision. When significant changes are needed, the Configuration Control Board (CCB) will authorize a new version of the software. Generally, this will require reprocessing of all of the previous data, starting at the level of the software revision, and continuing through all higher levels, to provide consistency. Each data granule will contain accounting information which will provide processing traceability through all levels.

B. New Version of Ancillary Data:

In the Level-1A processing, the platform ancillary data are appended to the Level-1A data without making any changes to the MODIS instrument data. If more accurate spacecraft position and attitude data become available later, and it is required that the more accurate data be used for earth location, etc., then the replacement can be made using utility software, without reprocessing the instrument data. This replacement will be reflected in the version number of the Level-1A product, and in the metadata.